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ANOMALOUS LUMINESCENCE OF SOME ORGANIC SOLVENTS

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Abstract

Luminescence from some organic solvents has been observed when irradiated by infrared (1060 nm) laser light. This effect is unusual in that the luminescence occurs in the visible spectrum while the excitation is in the infrared. Furthermore, a precondition is required for such an effect to occur, i. e. the sample must first be broken down (creation of a spark in the sample at the focus of the laser) before luminescence is observed. This condition is seemingly permanent.

Introduction

Many unusual effects have been observed from the interaction of Q-switched only laser light (694 nm) and liquids. From such an interaction involving benzene, water, carbon disulfide and others, weak luminescence has been reported.¹ The intensity profile of the emission was different from the laser profile having a long weak exponential tail. The lifetimes were calculated, and for carbon disulfide the value was about 100 nanoseconds. This was typical for most of the liquids, but since these liquids are essentially transparent to the laser wavelength, such results were not be expected. In a related experiment,² a ruby laser was used to induce a decrease in the transmission of carbon disulfide that was relatively constant over the wavelength region from 400 nm to 800 nm. Because this induced effect varied as the square of the laser intensity, two photon processes were considered to be the

dominant consideration in explaining the results. The examination of these unusual results have prompted some experimenters to conclude that such phenomena must be common to all liquids.¹ In our studies to determine the threshold for dielectric breakdown of liquids using the intense electric fields associated with a focused Q switched laser beam,³ we observed luminescence from such liquids as benzene, xylene, and pyridine. After breakdown occurred, i. e. a spark was generated in the liquid by the focused laser beam, further irradiation could not cause breakdown to occur again. Instead, the sample luminesced, outlining the path of the laser beam in the sample. This unusual event is the subject of this note and is presented as an observation of peculiar interest in the anomalous behavior of liquids to intense laser irradiation.

Experimental

Our experimental arrangement for detecting the luminescence from liquids is shown in figure 1.

The liquid cell holder is constructed with an inner cell where the breakdown occurs, and an outer cell incorporating an integrated focusing lens. The liquid to be tested is present in both parts of the

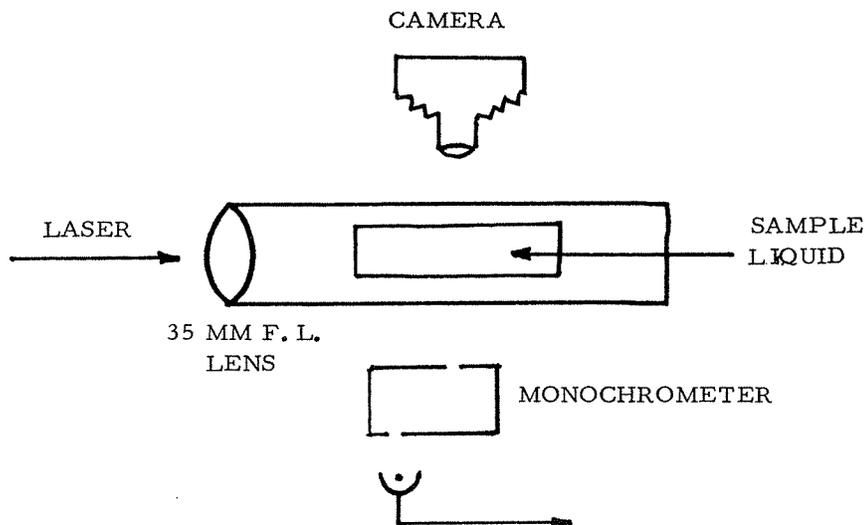


FIG. 1 Experimental arrangement for generating and detecting luminescence.

cell and serves two functions: to prevent damage to the lens by being in physical contact with the liquid, eliminating a large difference in the index of refraction between the two, and dramatically showing that luminescence occurs only in the liquid where breakdown has occurred. The internal cell is physically isolated from the outer. Internal cracking of the lens occurs when air is the medium on both sides.

A Q switched Nd laser (1060 nm and 40 nsec FWHM) was used to generate the luminescence. The detector consisted of a 1/4 meter Bausch and Lomb monochrometer and a 1P28 photomultiplier. The output of the photomultiplier was fed directly to a 454 Tektronix oscilloscope. The polaroid camera was used to picturize the luminescence and visually displayed the area of interaction.

In this study, the following routine was used to induce luminescence in the samples. The internal cell was positioned such that the impinging laser beam was focused into the sample. The laser intensity was adjusted to cause breakdown in the sample and the luminescence generated from subsequent laser irradiation was then recorded. That liquid materials do react with laser beams to cause breakdown has already been demonstrated, and the values of intensity required to produce such a phenomena have been recorded.³ Since this is a field effect, the laser wavelength used for breakdown is not the major determining factor, and the phenomenon occurs although the samples are essentially transparent (no optical absorption) to the laser beam.

In all the samples tested, breakdown was initially required after which luminescence was observed for each succeeding laser pulse. The laser did not have to be focused to observe the luminescence. By changing the irradiated sample to a fresh sample, luminescence would not occur until the laser power density was sufficient to cause a spark in the sample. After that, no further breakdowns were observed to occur even though the laser intensity was increased to a value greater than twice the threshold needed for

breakdown. One sample in particular was examined for possible photo products in a gas chromatograph and mass spectrometer with negative results.

The spectral content of the luminescence from benzene extended from at least 350 nm to 750 nm with the greater intensity towards the red region. The spectral curve of the luminescence generated from xylene showed similar characteristics. Visual observation confirmed the pinkish color from the luminescence. The emission curves exhibited a long exponential tail and the calculated lifetime of about 80 nanoseconds was very similar to that observed in carbon disulfide by the other experimenters previously cited.

Discussion

We have been able to generate luminescence in some solvents by the interaction of a Nd Q-switched laser. In these samples, initial breakdown generates the condition whereby visible luminescence occurs from interaction with an infrared laser (1060 nm).

The condition is relatively permanent. An irradiated solution of benzene continued to exhibit luminescence one year after breakdown. Specifically, the four samples that dramatically evinced this phenomenon were benzene, xylene, cyclohexane and pyridine. The spectral content of the two samples tested, benzene and xylene, showed similar intensity characteristics. We can only speculate that multiphotonic absorption is occurring since we observed visible luminescence induced by infra red radiation. Preliminary investigations as to possible photo products generating this anomalous luminescence have been made by use of gas chromatography and mass spectrometry and have produced negative results. A more rigorous examination of this phenomenon is anticipated where the relationship between the induced luminescence and the necessity for breakdown can be correlated.

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